



# Overview of the Phoenix Entry, Descent and Landing System

Rob Grover  
Jet Propulsion Lab

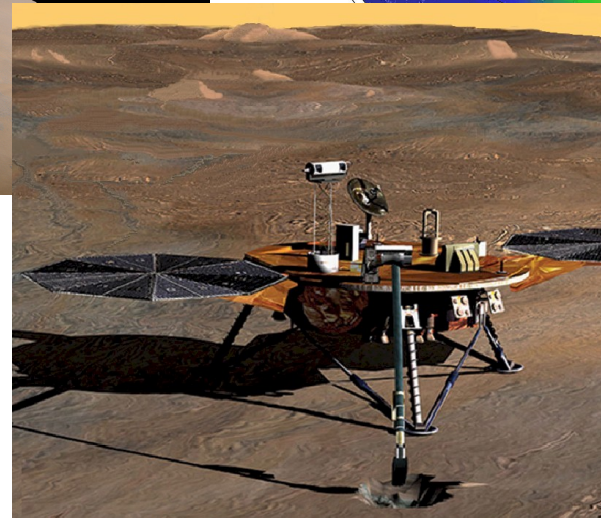
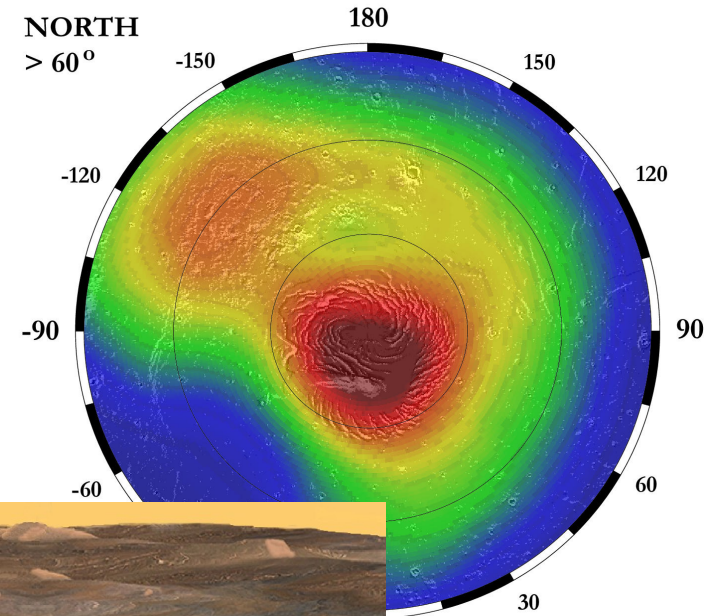
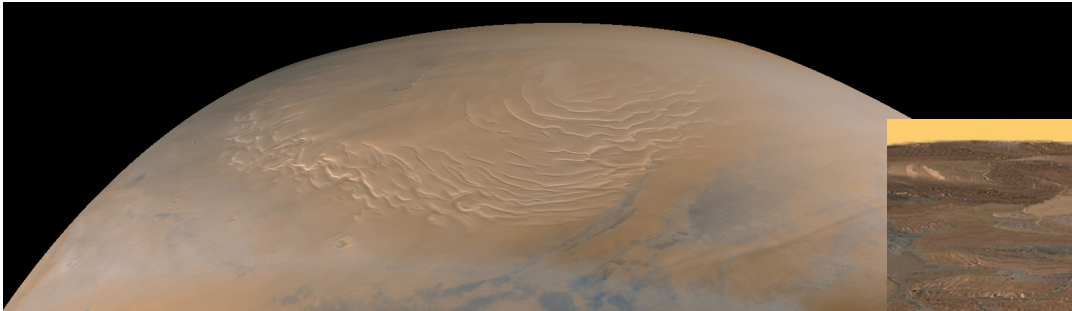


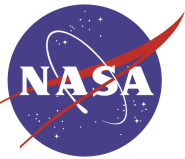


# Phoenix Mission Goals

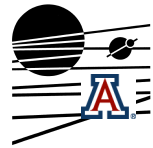
## Rebirth of the Mars 2001 Lander

- Study the history of water in Mars' arctic region.
- Search for habitable zones in Mars' arctic.
- Develop a robotic system to explore Mars.





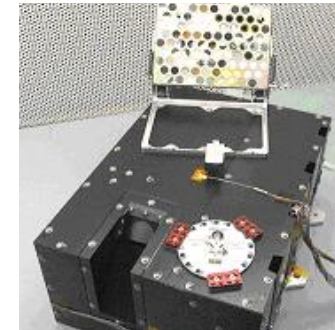
# Phoenix Payload



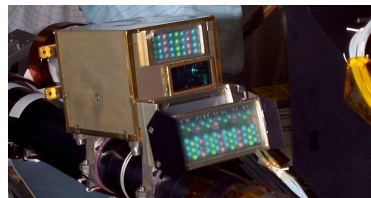
**Surface Stereo Imager (SSI)**  
University of Arizona



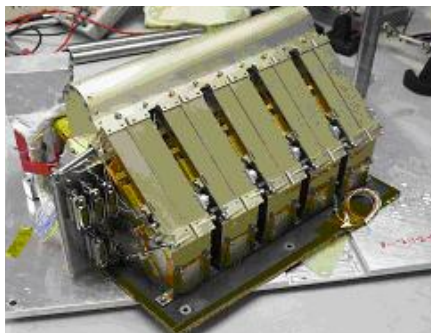
**Robotic Arm (RA)**  
JPL



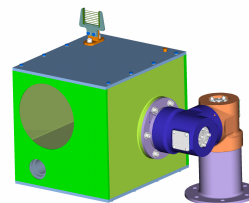
**Microscopy, Electrochemistry  
& Conductivity Analyzer  
(MECA)**  
JPL



**Robotic Arm Camera (RAC)**  
Max Plank Aeronomie



**Thermal Evolved Gas  
Analyzer (TEGA)**  
University of Arizona

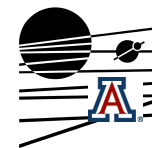
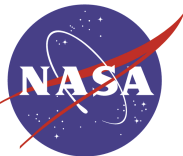


**Meteorological Package with scanning LIDAR**  
Canadian Space Agency



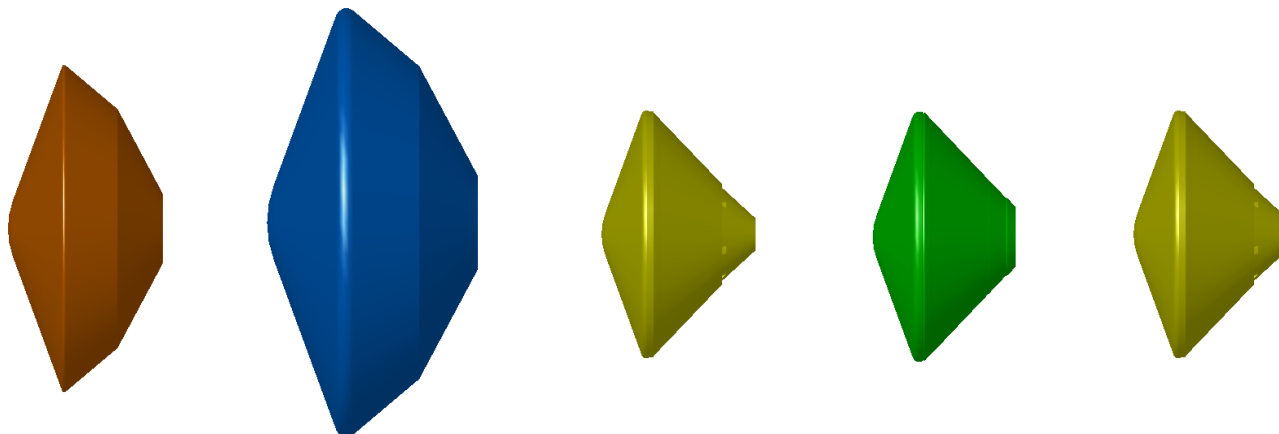
**Mars Descent Imager  
(MARDI)**  
MSSS



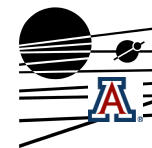
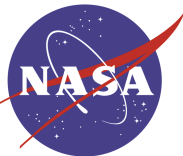


# Aeroshell/Entry Comparison

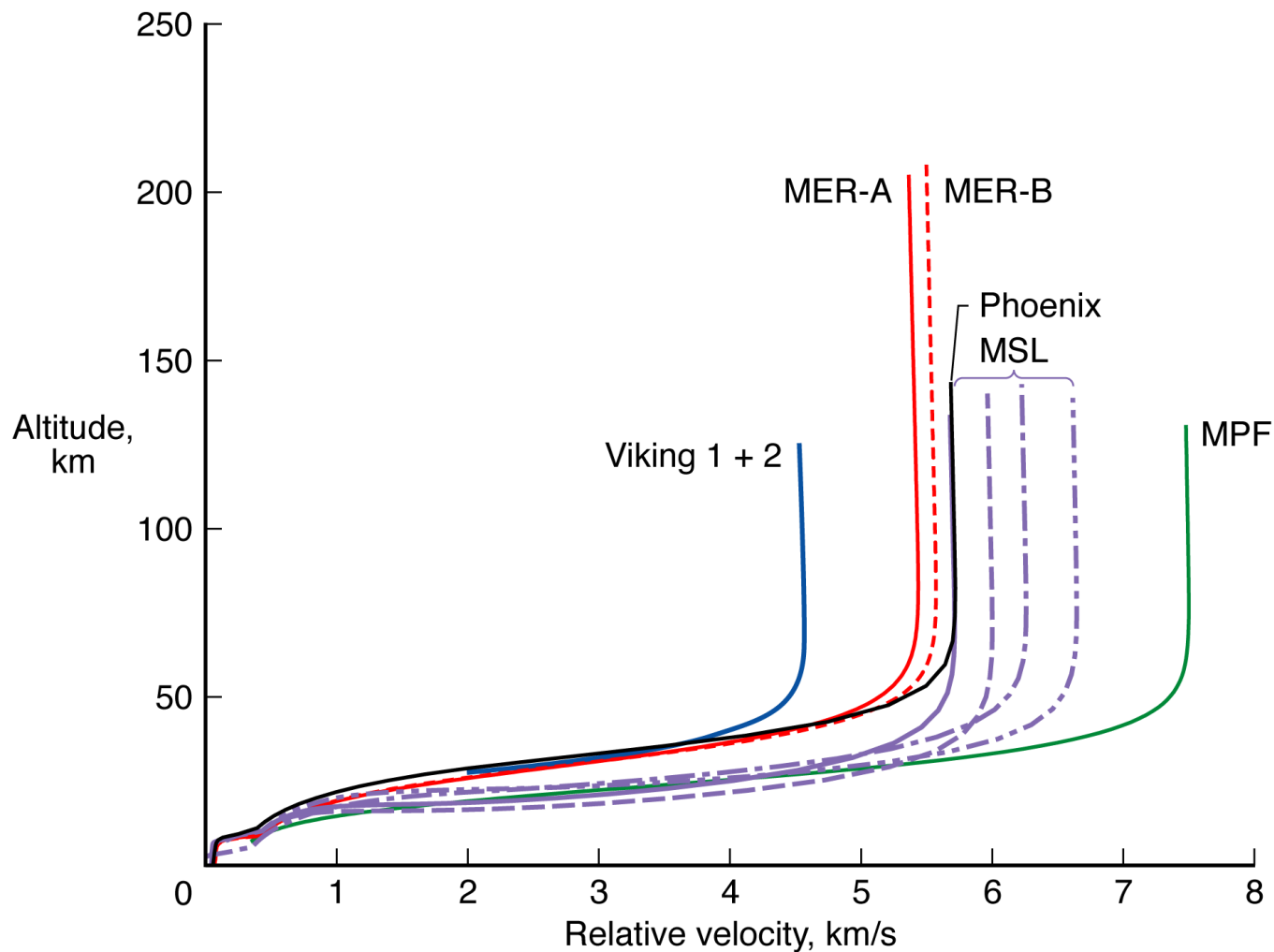
Entry Vehicles

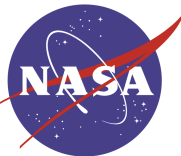


	Viking I, II	MSL	'01 Lander	MPF/MER	Phoenix
Diameter, m	3.505	4.572	2.65	2.65	2.65
Rel. Entry Velocity, km/s	4.5, 4.42	5.2 to 6.8	6.5	7.6/5.5	5.7
Rel. Entry FPA, deg	-17.6	-15.63 to -13.68	-12	-13.8/-11.5	-12.5
Entry Mass, kg	930	2400	588	585/840	602
$m/(C_D A)$ , kg/m <sup>2</sup>	63.7	94	62.9	62.3/89.8	69.3
$X_{CG}/D$ reference	0.221	0.27, TBD	0.25	0.27/0.26	0.25
Nominal $\alpha$ , deg	-11.1	-11	-3.5	0	-3.5
Nominal L/D	0.18	0.18	0.06	0	0.06

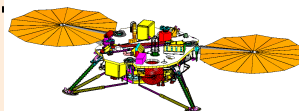
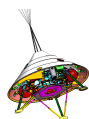


# Entry Trajectory Comparison





# Phoenix EDL Timeline



- Entry Turn Starts: E-6.3 min. Turn completed by E-5min.
- Cruise Stage Separation: E-5min
- Entry: E-0s, L-470s, **125 km\***, 5.7 km/s,  $\gamma = -12.5^\circ$
- Peak Heating: E+99s, L-301s, **45 km**, Peak Deceleration: E+117s, L-353s, 7g
- Parachute Deployment: E+250s, L-150s, **10 km**, < 350 m/s (Mach 1.45)
- Heat Shield Jettison: E+260s, L-140s, **9 km**
- Radar Activated: E+263s, L-137s, **8 km**
- Leg Deployments: E+293s, L-107s, **6.5 km**

**X-band DTE Closed / Open Loop**  
**UHF-band to Orbiter**

Landing at  
-3.5 km  
elevation above  
MOLA

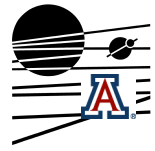
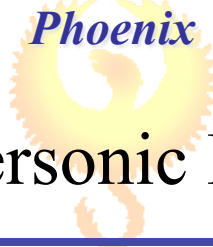
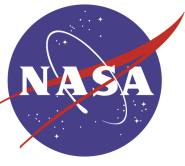
- Lander Separation: E+371s, L-29s, **0.74 km**
- Throttle Up: E+374s, L-26s, **0.57 km**
- Constant Velocity Achieved: E+393s, L-7s, **0.012 km**, 1.6 m/s
- Radar cutoff: E+395s, L-5s, **0.010 km**, 1.6 m/s

**X-band DTE Open-Loop**  
**UHF-band to Orbiter**

- **Touchdown:** E+400s, L-0s, **0 km**, 1.6 m/s
- Dust Settling: L+0 to L+15 min
- Fire Pyros for Deployments: L+7sec
- Solar Array Deploy: L+25min
- Begin Gyro-Compassing: L+100min

**X-band DTE**  
**UHF-band to Orbiter**

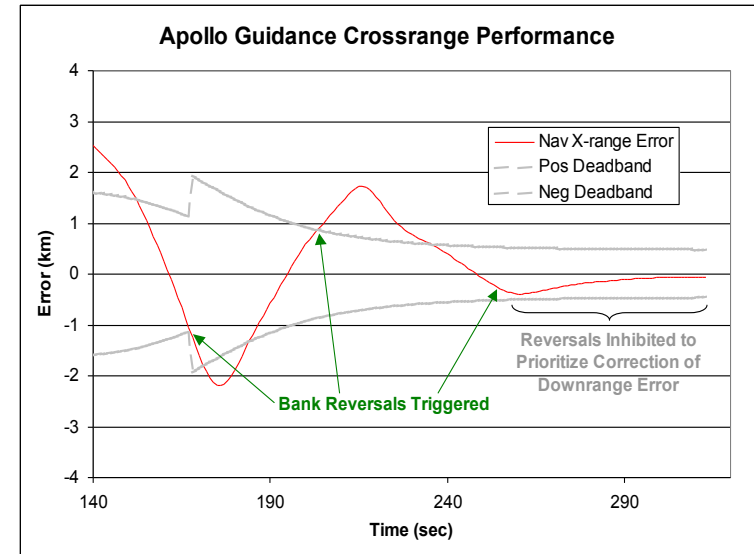
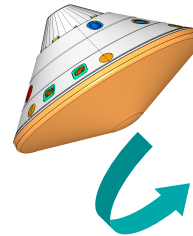
\* Altitude referenced to equatorial radius



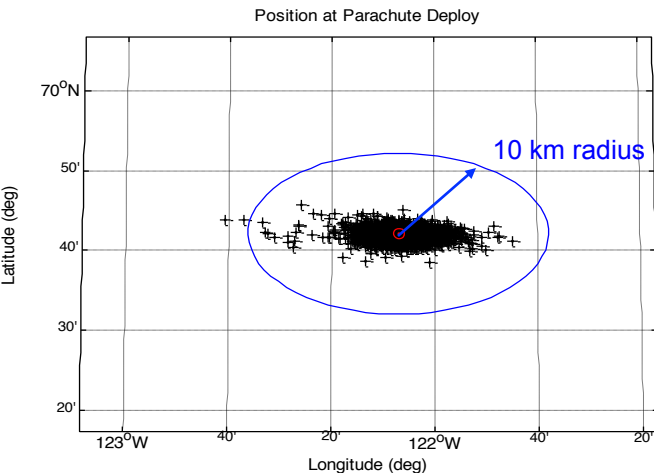
# Hypersonic Phase

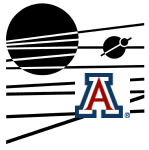
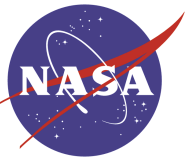
- Hypersonic Guidance will be Demonstrated by Using a Modified Version of the Apollo Earth-entry Guidance

- Terminal Point Range Control with Gain Matrix From Trajectory Perturbations
- Nominal Vehicle L/D = 0.06 (Alpha=3.5 deg)
- Utilizes Bank Control to Steer to Target at Chute Deploy
- Operates at 10 Hz



- No Requirement on Guidance Accuracy
- Performance will be Characterized by End-to-End Monte Carlos
- “Break-it” Testing Will Help Define Capability Limits
- Full “Lift Up”/“Lift Down” Does Not Impact Landed Success, Just Accuracy

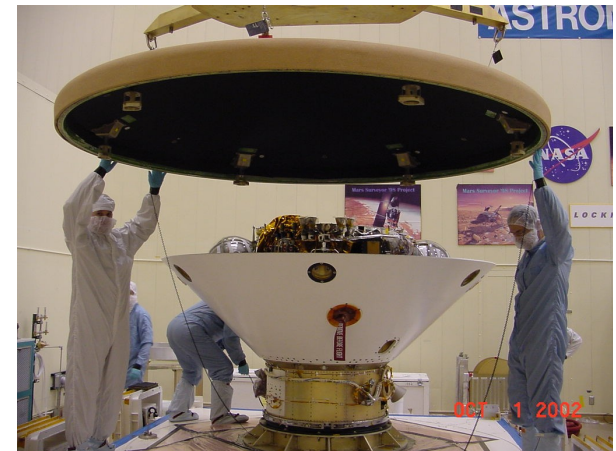




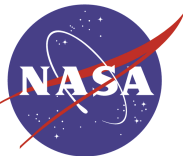
# Hypersonic Phase

- Begins with Entry Interface at 125 km Reference Altitude
- Dominated by Entry Heating
- *All Key Parameters Within Mars 2001 Design Envelope*

	<u>Phoenix</u>	<u>Mars '01 Requirement</u>
• Entry Velocity	5.76 kps	~6.5 kps
• Entry Errors, Delivery	0.20 deg	0.27 deg
• Entry Errors, Nav	0.15 deg	0.15 deg
• Max Heating	62 W/cm <sup>2</sup>	72 W/cm <sup>2</sup>
• Max Loads	9.5 g's	16 g's
• Max Bondline Temp	150 C	250 C



- Exist Hardware: Heatshield / Backshell Structure & TPS
- New Hardware: EDL Antennas & Assoc. TPS



# Parachute Phase

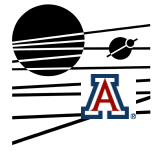
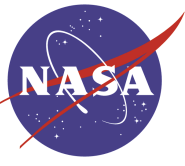
## Phoenix Parachute

• Viking Design Disc Gap Band (DGB)

- Mars 2001 Parachute: 13.4m Viking disc gap band
- Phoenix Currently 12.4m Viking Disc Gap Band
- Phase Begins with Parachute Mortar Firing
- Mars-01 Deploy Pushed to Viking Limit for Site Performance
- Current Lander Loads Capability Requires a Deploy Below 500 Pa

	<u>Phoenix</u>	<u>Mars '01 Requirement</u>
• Max Deploy Mach	1.7	2.25
• Max Deploy Qbar	485 Pa	1100 Pa





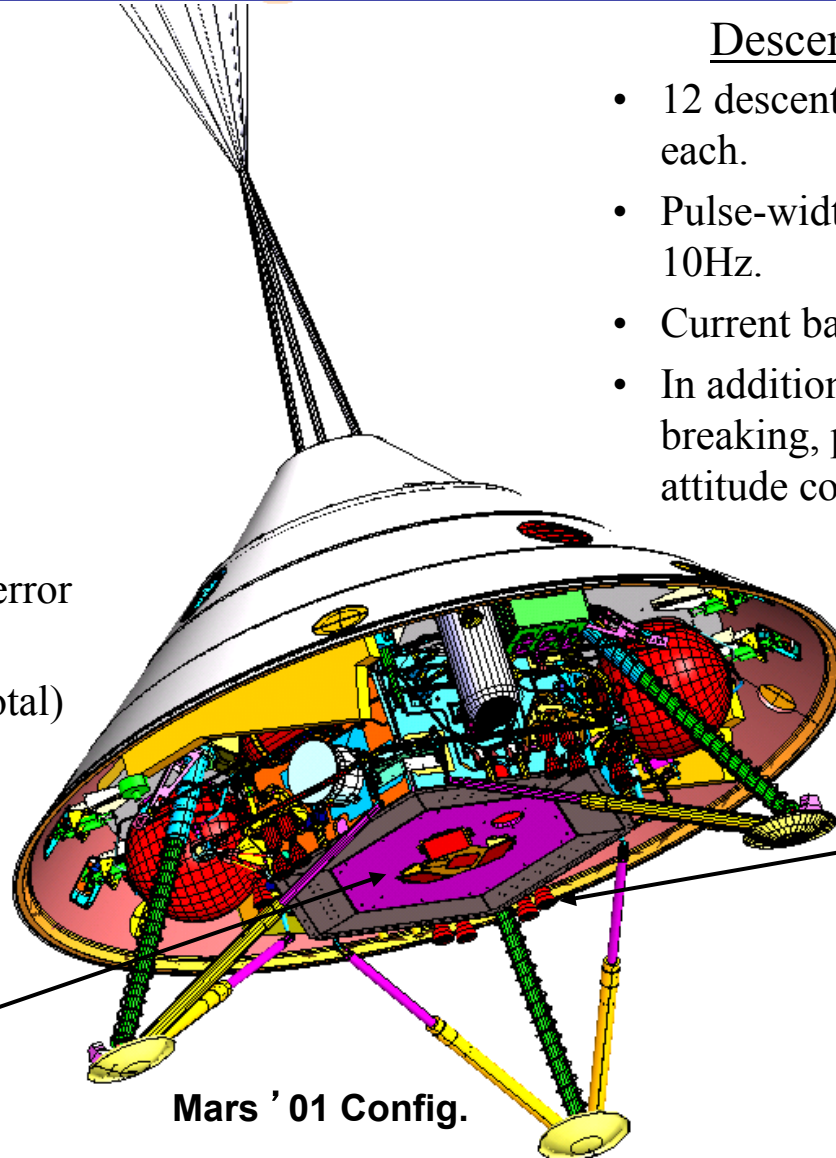
# Terminal Descent Phase

## Doppler Radar

- Altitude
  - Op. Range: 40-2400 m
  - Error:  $\leq 5\%$
- Velocity
  - Op. Range: 40-1400 m
  - Error:  $\leq 4\%$  ( $> 1\text{ m/s}$ )
  - Quantization: 0.82 m/s
- Phoenix Upgrade
  - Mitigates horizontal vel. error due to slopes
  - Extra set of antennas (8 total)
  - Alt. Range: 1-3700 m
  - Vel. Range: 10-2150 m
  - Quantization.: 0.40 m/s
  - Same error specs

## Descent Engines

- 12 descent engines,  $\sim 300\text{ N}$  each.
- Pulse-width modulated at 10Hz.
- Current baseline 3 full on.
- In addition to descent breaking, provides 3-axis attitude control.

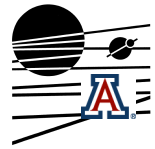
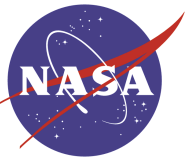


**Descent Engine (12)**

**Radar Antennas**

**Mars '01 Config.**

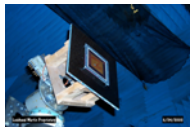




# EDL Communications

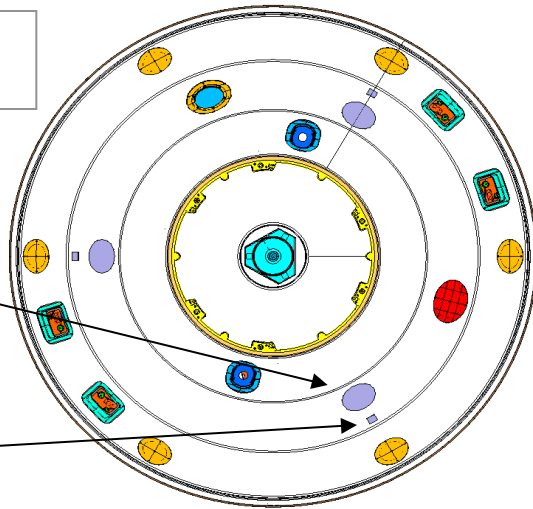
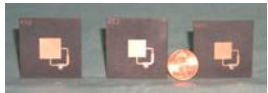
## KDR 3.3.5 Telemetry Durations

UHF ANTENNA



3 PLCS

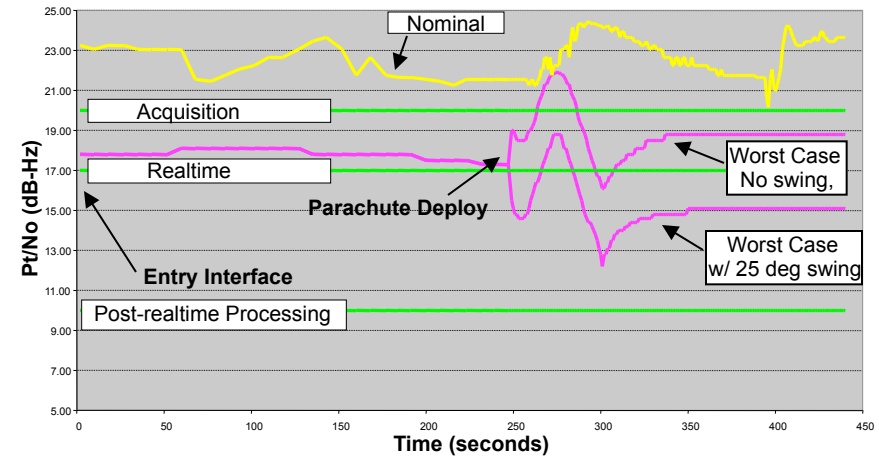
LGA  
3 PLCS



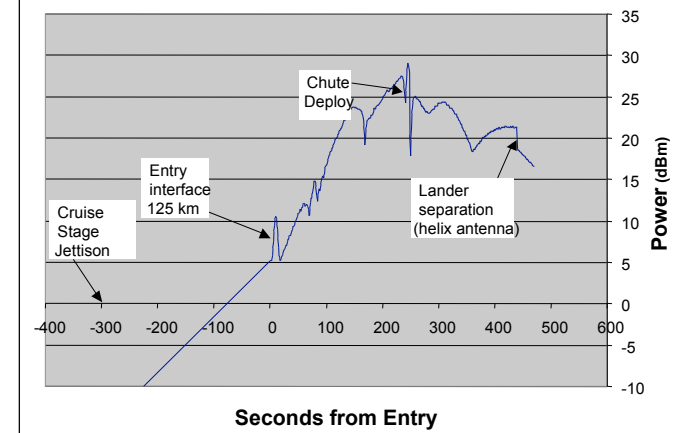
## Data Return

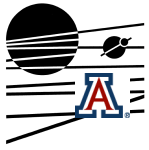
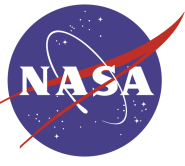
- UHF Comm during all of EDL
  - Direct link to Odyssey or MRO
  - 8 Kb/s Data Rate
  - Concern about Plasma blackout in Hypersonic
- X-Band Semaphores during all of EDL
  - Confirmation of Key Events
  - Capability to produce "fault" semaphores
  - Some level of performance data
- Link analyses to be refined as Mission Design matures

## Signal to Noise Ratio during entry



## Margin for 8 kbps





- Phoenix is a rebirth of the 2001 Lander using the same hardware and many of the same team members.
- Continuation of follow water strategy targeting subsurface ice in the northern polar region.
- First use of hypersonic guidance at Mars.
- Launching in 2007 and landing in 2008, it returns to propulsive soft landing with strong similarity to the Viking landings.